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Contributed paper

Design and manufacture of mini-beam collimators for macromolecular crystallography at the GM/CA-CAT at APS

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Since 2007, we have offered single collimators for mini beams of sizes 5, 10 and 20 μm as well as a 300 μm scatter-guard to accommodate the fully focused beam. The advantages of varying the beam size were obvious, better signal/background ratio and the capability to raster with a coarse, larger beam, then fine tune with one of the mini-beam options. The mini beams proved to be a technical and popular success; however, the switching of the single collimators often involved staff intervention. The single mini-beam collimators were the precursors to the development of a triple collimator. This implementation incorporated two mini-beam collimators and a 300 μm scatter-guard on one post. The design was improved by consolidation of fabrication from a single piece of molybdenum block. It significantly improved the robustness, ease of initial alignment, reduction of background and increased automation. However, experimenters were still left with a choice of either a (5, 10 and 300 μm)- or a (10, 20 and 300 μm)-triple collimator. Recently, a quad collimator was developed and fabricated to provide a selection of mini beams of 5, 10 and 20 μm and a 300 μm scatter-guard, on a single post. We will present the mechanical design of multi-collimators, results of measured beam flux through the collimator pinholes.

1. Overview of mini collimator

The National Institute of General Medical Sciences and National Cancer Institute Collaborative Access Team (GM/CA-CAT) dual canted-undulator beamlines at the Advanced Photon Source (APS) deliver high-intensity focused beams with a minimum focal size of 20 $\mu\text{m} \times 65 \mu\text{m}$ at the sample position (beamline 23-ID-D) (Fischetti *et al.* 2007). To meet the growing user demand for beams to study samples of 10 or less, a ‘mini-beam’ apparatus was developed that conditions the focused beam to either 5, 10 and 20 μm (full-width at half-maximum) diameter with high intensity. Advantages of using mini beam for macromolecule crystallography and the evolution from single to triple collimators have previously been described (Xu & Fischetti 2007; Sanishvili *et al.* 2008; Fischetti *et al.* 2009; Xu *et al.* 2009).

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2. Design and manufacture of the new Uni-body quad collimator

Recently, we developed a Quad collimator system that has been in use on both our beamlines since October 2009 (figure 1). The Quad collimator system includes the Quad collimator, the kinematic mounting system and high-resolution translation stages. The quad collimator design includes a robust monolithic ‘Uni-body’, four ‘caps’ and four pinholes. Four stepped beam path channels were machined into the monolithic body. This has significantly improved the robustness, ease of initial alignment and reduction of background scatter. It ensures the alignment of the forward scatter-guards that are smaller than $\text{Ø}250\text{ }\mu\text{m}$. The collimators capture the low-angle scatter thus keeping background scatter to a minimum. The compact footprint was a requirement to minimize obstruction of the high resolution, on-axis sample visualization microscope. The beam size is defined by a 2 mm-diameter platinum disk with a pinhole in the centre (Ted Pella Inc.). The disk is $600\text{ }\mu\text{m}$ thick and tapers to $150\text{ }\mu\text{m}$ at the position of the aperture.

Since the minimal wall of the molybdenum ‘Uni-body’ quad collimator is only 0.28 mm thick and hard to machine, the small exit holes were manufactured using the Electrical Discharge Machining (EDM) method. The connecting support strip was brazed to the molybdenum body. The calculation result of transmission of 0.28 mm molybdenum at 12 keV is 0.51×10^{-6} , which is negligible (Xu & Fischetti 2007).

The positional reproducibility of the mini-beam collimator kinematic system was measured by optical metrology. The root mean square (RMS) deviation from the mean position was $0.24\text{ }\mu\text{m}$ in both X- and Z-directions (Xu & Fischetti 2007).

Two high-resolution micro translation stages are combined to form an XY system for the collimators alignment. The travel range is 15 mm for both stages. The design resolution is $0.007\text{ }\mu\text{m}$ with a repeatability of $0.1\text{ }\mu\text{m}$. The whole system stability is $\pm 0.1\text{ }\mu\text{m}$.

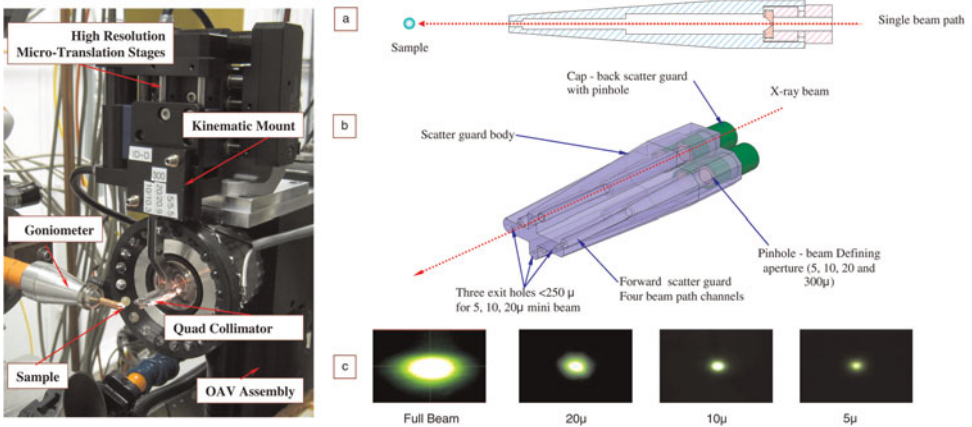


FIGURE 1. Left: the quad collimator installed on the beamline. Right: (a) cross-sectional view of an individual collimator, (b) semi-transparent, three-dimensional view of the quad collimator with its essential components and (c) beam imaged by X-ray fluorescence from an yttrium aluminium garnet (YAG) crystal mounted at the sample position.

3. Measurement results

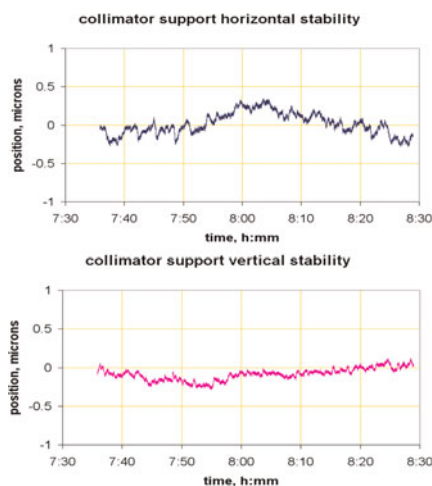
3.1. Beam flux through the collimator pinholes (Table 1)

	23-ID-B		23-ID-D	
	Beam size (μm)	Intensity (photons s^{-1})	Beam size (μm)	Intensity (photons s^{-1})
Natural focus	25×120	5×10^{12}	20×65	1×10^{13}
Mini-beam collimator	$\varnothing 20$	5×10^{11}	$\varnothing 20$	1×10^{12}
	$\varnothing 10$	1×10^{11}	$\varnothing 10$	2×10^{11}
	$\varnothing 5$	4×10^{10}	$\varnothing 5$	7×10^{10}

TABLE 1. Beam sizes and intensities are listed for the focused and mini beams. The pinhole selects the central part of the focused beam.

3.2. Mini-collimator system beam stability and reproducibility test results

The quad collimator system stability was measured by an LDS-Vector Electronic Autocollimator (Newport). The stability was $0.17 \mu\text{m}$ in horizontal direction and $0.13 \mu\text{m}$ in vertical direction (Xu *et al.* 2009). The positional reproducibility of the mini-beam collimator on the kinematic mount was measured by optical metrology (Measurement by Keyence Surface Scanning Laser Confocal Displacement Meter (In Profile Mode). The RMS deviation from the mean position was $0.24 \mu\text{m}$ in both X- and Z-directions for 34 repeated manual mount and dismount operations (Xu & Fischetti 2007).



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